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Studies on the Trace Elements in Soil-Plant-Animal System. III. Improvement of Copper Status of Herbage Resulting from Application of Copper Sulfate to Grazing Field.

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Summary

Soil pH, available Cu in soil and the mineral composition of herbage were determined on a Cu deficient field with the surface application of either copper sulfate or lime on the Kawatabi farm of Tohoku University. Soil pH was slightly lower in the surface horizon of the copper sulfate application plot than in that of the lime application plot. The topdressed Cu was mostly retained at the surface horizon of the soil. This suggests that the applied Cu might form the stable Cu-organic matter complex in the surface soil which was rich in organic matter. The application of copper sulfate to the grassland improved the Cu concentration in herbage. That is to say, Cu concentration in herbage went up to the level for the satisfaction of the minimum requirement for beef cattle with an application of 5 kg copper sulfate per 10 a and for dairy cattle with an additional similar application in the following year. The lime application, 200 kg per 10 a year for two years, had no influence on the Cu concentration in herbage. The other mineral concentrations in herbage were slightly affected by copper sulfate or lime applications as copper sulfate applications tend to raise Zn, Mn and Mg, and lime applications raise Ca in herbage.

The previous studies (1, 2) showed the soil at the Kawatabi farm of Tohoku University was deficient in Cu, and the Cu levels in the herbage and blood of cattle were low as compared with those at the grazing fields in other regions of the Tohoku district in Japan. It was known that the Cu deficiency in grazing animals was mainly alleviated by the injection of copper compounds at such intervals as were required to maintain plasma Cu concentrations at the normal level and the improvement of the Cu content in herbages by the applications of copper sulfate or copper oxide to pasture field (3-6).

The experiment reported here was designed to investigate the improvement of the Cu level in herbages by the application of copper sulfate to the grazing field and to determine whether the liming of the grazing field depresses the Cu absorption of herbage plants owing to the rise of soil pH or not.

Materials and Methods

The study was conducted on 2.4 ha of the grazing field at the Kawatabi farm. The herbage species in the field were mainly composed of orchard grass, red top and white clover. The experimental field was divided into two treatment plots, each 1.2 ha, and on them was applied either 5 kg of $CuSO_4 \cdot 5H_2O$ (copper sulfate application plot) or 200 kg of lime (lime application plot) per 10 a in mid-April in both 1974 and 1975. Both treatment plots received the fertilizer at the rate of 15 kg of N (urea), 6 kg of P (superphosphate) and 5 kg of K (potassium chloride) per 10 a every year.

Grazing procedure was carried out by using 5 Holstein steers with rotation grazing among 3 paddocks into which each treatment plot was further divided. Herbage and soil samples were collected from four points in each treatment plot, 9 times for herbage and 5 times for soil during the grazing period from 1974 to 1975. Soil samples were taken from 0 to 20 cm, each 10 cm in depth, in 1974 and from 0 to 10 cm, each 5 cm in depth, in 1975. Soil pH (with H_2O) and extractable Cu in soil with 1 N HCl were measured on air-dried soil samples. Herbage samples collected for each herbage species, orchard grass, red top and white clover, were dried at 80°C for 48 hours and then preserved for analysis. Mineral concentrations in soil and herbage were determined with the atomic absorption flame photometer after pre-treatment as previously reported (1).

Results and Discussion

1. Soil pH and Cu in soil.

The pH values of soil were from 5.3 to 5.6 as shown in Table 1. Soils of surface horizon in the lime application plot tended to show a little higher pH value than those in the copper application plot, but the difference of pH values

TABLE 1. *The pH (water) of the soil from the pastures applied with copper sulfate and lime.*

Treatment	1974			1975			
	Soil depth	Sep. 5	Nov. 25	Soil depth	May 12	Aug. 19	Oct. 21
Copp. appl.	0–10 cm	5.3	5.5	0– 5 cm	5.3	5.3	5.3
	10–20	5.5	5.5	5–10	5.5	5.5	5.5
Lime appl.	0–10	5.5	5.3	0– 5	5.4	5.4	5.5
	10–20	5.6	5.3	5–10	5.4	5.3	5.4

TABLE 2. *Concentrations of Cu extracted from soils with 1 N HCl*
(ppm ± S.D.)

Treatment	1974			1975			
	Soil depth	Sep. 5	Nov. 25	Soil depth	May 12	Aug. 19	Oct. 21
Copp. appl.	0 – 10 cm	3.93 ±0.45	3.98 ±0.62	0 – 5 cm	11.33 ±5.40	4.57 ±0.45	9.58 ±6.42
	10 – 20	3.28 ±0.43	3.43 ±0.72	5 – 10	4.27 ±0.13	3.83 ±0.23	3.83 ±0.29
Lime appl.	0 – 10	3.38 ±0.36	3.58 ±0.18	0 – 5	3.98 ±0.17	3.80 ±0.39	3.60 ±0.10
	10 – 20	3.28 ±0.45	3.25 ±0.10	5 – 10	3.63 ±0.33	3.58 ±0.28	3.33 ±0.03

between treatment plots was not significant throughout the period of investigation.

Table 2 shows the concentrations of Cu extracted from soil with 1 N HCl. The extractable Cu in soil was high in surface horizons of 0-10 cm in 1974 and 0-5 cm in 1975 in both treatment plots. The effect of the applied copper sulfate on the extractable Cu concentrations in soils was small in soil 0-10 cm in depth in 1974, but it was notable in soil 0-5 cm in depth in 1975. As can be shown from the data in 1975, the topdressed Cu was mostly retained at the surface horizon of the soil and the leaching to the lower horizon was little. Such limited distribution of Cu suggested that the applied Cu had transformed into unmobile type as a result of the forming copper-organic matter complex in surface layer of Andosol (6). Therefore it was speculated that the small change of Cu concentration in soil 0-10 cm depth in 1974 was due to dilution of the surface soil, retaining Cu, with the soil of lower horizon.

2. *Minerals in plants.*

The mean values of mineral concentrations in herbages are shown in Table 3. The mean Cu concentrations in herbages ranged from 5.1 to 6.4 ppm in the copper sulfate application plot and 2.1 to 3.2 ppm in the lime application plot in 1974, and from 9.2 to 13.2 ppm in the copper sulfate application plot and 2.6 to 3.7 ppm in the lime application plot in 1975. These Cu contents of herbage in the copper sulfate application plot satisfied the minimum requirement of Japanese Feeding Standard for beef cattle (8), but not for dairy cattle (9) except in 1975. Cu concentrations in herbage differed among herbage species as shown in the following order: orchard grass > red top > white clover in both treatment plots in 1974, and white clover > red top > orchard grass in the copper sulfate application plot, and red top > white clover > orchard grass in the lime application plot in 1975. The Cu concentrations in herbages in the copper sulfate application plot were

TABLE 3. *Mineral concentrations of herbages in grazing pastures applied with copper sulfate and lime.* (*ppm or **% ±S.D.)

		*Cu	*Zn	*Fe	*Mn	**Ca	**Mg
1974							
Orchard grass	Copp. appl.	6.4±2.5	27± 6	86±18	60± 7	0.27±0.01	0.23±0.07
	Lime appl.	3.2±1.4	25± 3	83±16	58± 6	0.30±0.05	0.23±0.04
White clover	Copp. appl.	5.1±1.8	26± 7	111±28	47± 8	1.27±0.21	0.41±0.05
	Lime appl.	2.1±0.9	26± 7	114±27	47± 8	1.23±0.25	0.38±0.06
Red top	Copp. appl.	5.6±1.9	33± 8	99±28	99±31	0.39±0.04	0.30±0.04
	Lime appl.	2.5±0.5	31± 7	101±23	94±33	0.38±0.07	0.28±0.03
1975							
Orchard grass	Copp. appl.	9.2±0.9	23± 3	71±21	76±17	0.25±0.02	0.23±0.04
	Lime appl.	3.0±0.6	23± 3	83±10	48±13	0.34±0.01	0.23±0.04
White clover	Copp. appl.	13.2±9.4	33±19	150±66	68±20	1.95±0.96	0.55±0.21
	Lime appl.	2.6±0.3	24± 6	108±16	45± 8	1.52±0.49	0.39±0.02
Red top	Copp. appl.	10.7±2.6	35± 4	76±16	135±56	0.36±0.03	0.25±0.03
	Lime appl.	3.7±1.8	31± 3	74±12	86±31	0.41±0.07	0.25±0.03

higher in 1975 than 1974, and were about two and three times those in the lime application plot in 1974 and 1975, respectively. That is to say, the effect of applied copper sulfate on the Cu concentration in herbage was greatly extended by applying it twice. It is noteworthy that white clover in the field where copper sulfate was applied showed an extremely high Cu concentration. As mentioned in a previous paper (1), legumes were not always richer in Cu concentrations than grasses on soils with very low levels of available Cu. Such improvement of Cu concentrations in white clover in the copper sulfate application plot in 1975 suggests that the soil was satisfactorily amended on the Cu status for pasture plants in that field. The other mineral concentrations in herbage were slightly affected by copper sulfate or lime applications, as the copper sulfate application tended to raise Zn, Mn and Mg, and the lime application to raise Ca concentrations in herbage. It was supposed that the slight increase of mineral concentration in herbage caused by the copper sulfate application was attributed to the increase of the solubility of minerals in soil occurring from the decrease of soil pH. The mean mineral concentrations in herbage also differed among herbage species. Zn, Fe, Mn, Ca and Mg concentrations in herbage were in the following order; Zn: red top>orchard grass=white clover, Fe: white clover>red top>orchard grass, Mn: red top>orchard grass>white clover, Ca: white clover>red top>orchard grass, Mg: white clover>red top>orchard grass.

Table 4 shows the seasonal variation of Cu and Ca concentrations in herbages in both treatment plots. Cu of herbage in the copper sulfate application plot initiated an increase in spring and attained the high level in summer of the first

TABLE 4. *Seasonal variation of Cu and Ca concentrations in herbages.*

		1974						1975		
		May 7	May 27	Jun. 19	Jul. 5	Sep. 16	Oct. 11	May 8	Aug. 19	Oct. 4
Cu (ppm)										
Orchard grass	Copp. appl.	4.2	3.9	4.7	8.7	9.6	7.1	10.0	9.3	8.3
	Lime appl.	2.7	2.1	2.7	2.9	5.9	2.8	2.3	3.3	3.4
White clover	Copp. appl.	4.6	2.8	6.3	3.3	6.5	7.1	24.0	9.2	6.5
	Lime appl.	2.0	1.4	1.8	1.6	4.0	1.9	2.3	2.9	2.5
Red top	Copp. appl.	7.3	2.5	5.7	7.7	5.4	4.9	13.3	10.8	8.0
	Lime appl.	2.6	1.8	2.6	2.6	3.3	2.0	1.7	4.3	5.0
Ca (%)										
Orchard grass	Copp. appl.	0.27	0.25	0.27	0.27	0.28	0.29	0.26	0.27	0.23
	Lime appl.	0.29	0.25	0.27	0.29	0.32	0.38	0.35	0.34	0.34
White clover	Copp. appl.	1.50	1.44	1.35	1.10	0.95	1.30	3.06	1.43	1.36
	Lime appl.	1.60	1.48	1.09	0.97	1.12	1.11	2.06	1.40	1.11
Red top	Copp. appl.	0.37	0.40	0.38	0.34	0.46	0.40	0.37	0.39	0.33
	Lime appl.	0.34	0.39	0.28	0.39	0.50	0.40	0.48	0.39	0.35

year except for white clover on July 5, 1974, whereas the Cu concentrations in herbage in the lime application plot tended to show an increase from summer to autumn similar to the untreated field as mentioned in the previous paper (1). Ca in herbage was low from spring to summer in grasses but from summer to autumn in legume, and high in autumn in grasses but in spring in legume. The low mineral concentrations of May 23 were attributed to the relatively higher productivity of grasses in the reproductive stage.

In this field experiment, it was proved that the application of copper sulfate to the grassland amended the Cu concentrations in herbage in a Cu deficient grazing field. Cu concentrations in herbage went up to the level of the minimum requirement of Japanese Feeding Standard for beef cattle (8) with the application of 5 kg copper sulfate per 10 a and for dairy cattle (9) with an additional second application. Lime application, 200 kg per 10 a • year for two years, to the field did not prevent the Cu accumulation in herbage compared with the non-treated field (1).

The effect on cattle of copper sulfate and lime application to grazing field will be mentioned in following report.

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